BRNO UNIVERSITY OF TECHNOLOGY FACULTY OF INFORMATION TECHNOLOGY

Excel@FIT 2024
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Robotic Manipulator Exploiting RC Components and Servos

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Abstract
This contribution describes a robotic arm, thatcan be assembled at home using only 3D printing, common hobby tools, and off-shelf components. The result of this work is a robotic arm that, in its basic configuration, is equipped with a distributed system of several microcontrollers and sensors that provide sensing of the position of the robotic arm in space and collision detection with the environment. It is also an advantage that the robotic arm can be programmed in common programming and scripting languages, such as C, C++, Python, and many others, as well as support and integration with the ROS2 framework. This contribution is based on my master's diploma thesis, which contains a more detailed description of the proposed robotic arm, its parameters, and an overview of the final implementation.

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1. Introduction

The robotics industry is constantly evolving like many other industries. Not only established companies but also various open-source projects and industry enthusiasts are contributing to it. The main motivation for this robotic arm is to create a device that will be simple and suitable for teaching and learning, testing new approaches and technologies.

A common problem with industrial and collaborative robotic arms is the closed nature of their robotic systems. For some brands, it is often necessary to go through programmer training or required to use special paid software, not to mention the need to ensure operator safety when using the robotic equipment.

In contrast, the proposed robotic arm aims to provide an open system with the possibility of easy modification by the user, as well as the possibility of using open-source software. In the case of hardware, the robotic arm should include off-shelf components that can be easily added, replaced, upgraded, or modified.

All of the above-mentioned features are ensured due to the open-source characteristics and approach taken in the creation of this project with an emphasis on future modifications and developments.

2. Existing solutions

Many similar solutions exist and some of them have served as inspiration for this robotic arm. Some solutions have innovative designs. For example, their bodies are flexible [1] or they look like human hands [2]. I want to briefly mention some of the features, positives, and negatives of the three more common designs, like the Kawasaki ASTORINO [3] and ARCTOS v0.16 [4]. Both robotic arms are made using 3D printing for ease of repairability in the event of damage and using NEMA standard motors for the motion.

In the case of software, the most advanced is Niryo Ned2 [5], which has a wide variety of different supported open-source projects and frameworks, on the other hand, Kawasaki ASTORINO has the most closed operating system, which supports only proprietary programming language. As the control unit, all three robots use development boards, such as RassberryPI, Arduino, or Teensy.

3. Proposed solution

The proposed robotic arm has a full range of degrees of freedom of movement, i.e. 6 degrees of freedom, which means that it must be equipped with six joints otherwise, the kinematics of this robotic arm would not be able to cover the full range of freedom.

The motion of the robotic arm has to be precise, and at the same time, the position of individual joints has to be reported as the feedback. In the case of other sensing methods, a robot should be able to detect overload and collision with the environment.

Motion control of the robotic arm must be provided using a microcontroller that can communicate with a higher-level system in the form of a PC, which can send instructions with the desired poses and also serve to display device for feedback and other telemetry. Communication between the controller and the individual components and sensors of the robotic arm should be via standard communication protocols and buses.

The resulting robotic arm, as you can see in Figure 1. was designed based on the parameters established in the presented solution, with several improvements added. The body of the robotic arm is designed so that the majority of the components are printable on a 3D printer, with a print volume of 250x210x210mm. Except for the two parts, this intention was successful. As you can see in Figure 1., larger components are screwed together from smaller parts, and the individual subassemblies of the robot links. The arm

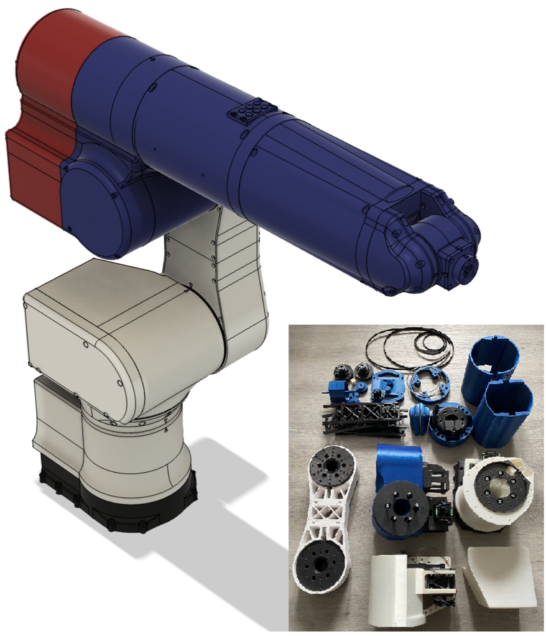

Figure 1. The final design of the robotic arm on the left and physical subassemblies on the right.

is driven by two NEMA14 [6] and four NEMA27 [6] stepper motors. All motors are equipped with MakerBase [7] drivers which feature a CANbus [8], are powered by 24V DC, and contain shaft position sensing. The individual joints of the robotic arm are equipped with compound planetary gearboxes, which have been made by 3D printing except for some miniature bearings and guide axles. Standard GT3 and 3M HTD belts take care of the power transmission from the motors to the gearboxes, which results in final gear ratios from 1:17.5 up to 1:125.

The robotic arm is also equipped with position sensors in the form of absolute magnetic encoders located on each joint. Another type of sensor used in the robotic arm is the weight sensor, which is located inside of the gearboxes of the first four joints. The last two joints are taken care of by two strain gauges, which are also located in the gearboxes. The last type of sensor is a 3-axis gyroscope in combination with an accelerometer, which takes care of shock and collision detection.

The robot is equipped with three ESP32 [9] microcontrollers, which are distributed across the body, and all sensors are connected to them. A RassberryPi 4B [10] microcomputer is used as the main control unit and is connected with motor drives and ESP32 microcontrollers via CANbus 2.0B [8], and sends commands and receives feedback via this bus. The RassberryPi can then be connected to a higher-level system using an ethernet or wifi interface. A computer as the master system, is used to send commands with the required positions. For this, tools of the ROS2 [11] framework can be used.

4. Result

Selected important tests have been performed, like measurement of maximal reach and payload. The robotic arm can reach up to 1020mm, and the payload capacity was tested up to 200g of payload. More advanced tests are still pending, like precision, repeatability, hard collision detection, payload overload, and speed tests. These tests will be done, after the presentation at the conference, because there is a high possibility that the robotic arm can be damaged.

5. Conclusion

The goal of the work was to design and build a robotic arm. The goal has been reached, and the robotic arm, by its open-source nature, is ready for the possibility of education and development of new approaches in the field of robotics. Also, more tests can be done and some features can be improved.

Acknowledgements

I would like to thank my supervisor Prof. Dr. Ing. Pavel Zemčík de. h. c. for guidance on the thesis, Mr. Zdeněk Juříček, Jr. for 3D printing support, and doc. Ing. Vítězslav Beran Ph.D. for OpenSpace services.

References

[1] Matsuda R., Mavinkurve U. K., Kanada A. , Honda K., Nakashima Y. and M. Yamamoto *Design of 3D-printed Flexible Robotic Arm with Bendable and Extendable Capacity*. Atlanta, Georgia, United States: International Symposium on System Integration (SII), IEEE/SICE 2023, pp. 1-5, doi: 10.1109/SII55687.2023.10039169. [cit. 18.4.2024]. Available at: https://ieeexplore.ieee.org/document/10039169.

[2] Gent E. *Robot Hand With Working Tendons Printed in One Go* [online]. Zurich, Switzerland: IEEE Spectrum, 2023 [cit. 18.4.2024]. Available at: https://spectrum.ieee.org/3d-printed-robot-hand.

[3] *Kawasaki ASTORINO, Documentation for an incomplete machine* [online]. Warsaw, Poland: ASTOR Sp. z o.o., 2022 [cit. 20.4.2024]. Available at: https://astorino.com.pl/wp-content/uploads/2023/02/Kawasaki_Robotics_ASTORINO_safety2022.pdf.

[4] *ARCTOS v0.1 Assembly manual* [online]. Moscow, Russia: ARCTOS Robotics, 2023 [cit. 20.4.2024]. Available at: https://drive.google.com/file/d/1ePPefzkEJzm6X44uw4x01dr6atSM6yGU/view.

[5] *Nyrio Ned2* [online]. Wambrechies, France: Niryo, 2023 [cit. 20.4.2024]. Available at:https://niryo.com/products-cobots/robot-ned-2/.

[6] *Motion/Position Control Motors, Controls and Feedback Devices*. Rosslyn, Virginia, United States: National Electrical Manufacturers Association, 2006.

[7] MKS Servo42D/57D_CAN V1.0.4 User manual [online]. Shenzhen, China: MakerBase3D Ltd., 2023 [cit. 18.4.2024]. Available at: https://github.com/makerbase-motor/MKS-SERVO57D/blob/master/User%20Manual/MKS%20SERVO42%2657D_CAN%20User%20Manual%20V1.0.4.pdf.

[8] *CAN Specification Version 2.0*. Stuttgart, Germany: Robert Bosch GmbH, 1991.

[9] *ESP32Series Datasheet v4.5* [online]. Shanghai, China: Espressif Systems inc., 2024 [cit. 20.4.2024]. Available at: https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf.

[10] *Raspberry Pi 4 Model B [online]*. Cambridge, England: Raspberry Pi Ltd., 2024 [cit. 20.4.2024]. Available at: https://datasheets.raspberrypi.com/rpi4/raspberry-pi-4-datasheet.pdf.

[11] Macenski S., Foote T., Gerkey B., Lalancette Ch. and Woodall W. *Robot Operating System 2: Design, architecture, and uses in the wild*. Washington DC, United States: Science Robotics 2022, doi: 10.1126/scirobotics.abm6074. [cit. 20.4.2024] Available at: https://www.science.org/doi/abs/10.1126/scirobotics.abm6074.